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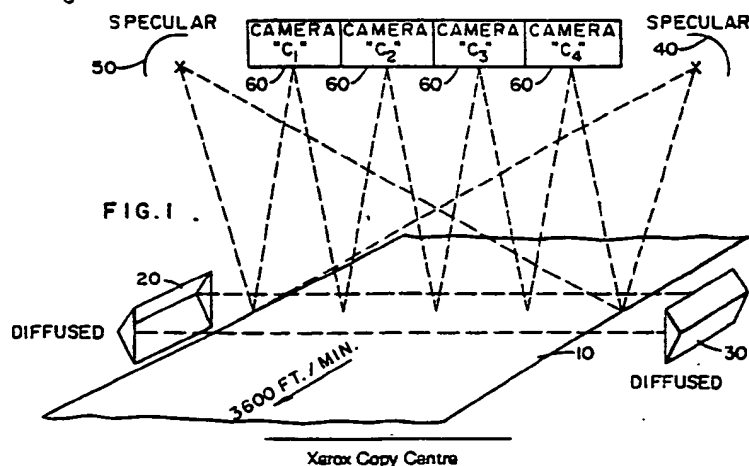
㉕ Applicant: **ALUMINUM COMPANY OF AMERICA**
1501 Alcoa Building Mellon Square
Pittsburgh, PA 15219(US)

㉖ Inventor: **Adomaitis, Paul Regis**
144 Old Gate Road
Trafford Pennsylvania(US)
Inventor: **Brouwer, Nicholaas Louis**
168 Watson Drive
Apollo Pennsylvania(US)
Inventor: **Hobl, Bernard John**
R.D. 1 Box 621A
New Kensington Pennsylvania(US)

㉗ Representative: **Ballila, Iain Cameron et al**
c/o Ladas & Parry Isartorplatz 5
D-8000 München 2(DE)

㉘ Method for detection of surface defects.

㉙ The invention comprises a system for continuously inspecting the surface of a moving object for defects therein while illuminating the surface of the moving object with both specular and/or diffused light of selected wavelengths, automatically detecting the presence of a defect, and automatically transmitting a visual image of a defect, when detected, to a storage device capable of subsequent permanent display and electronic characterization of the visual image containing the defect.



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This invention relates to a method for inspecting the surface of a moving metal e.g. aluminum surface. More particularly, the invention relates to a system for automatically detecting flaws in the surface of a moving object and storing a visual image of the flaw for inspection thereof. Strobed illumination or electronic or mechanical shuttering are used to arrest surface motion to provide an undistorted view of surface characteristics.

The inspection of objects for defects using camera means has been used by Kendrick et al U.S. Patent 3,230,305 for the automatic inspection and rejection of bobbins of yarn; by Henry U.S. Patents 4,232,336 and 4,240,110 for detecting irregularities in crimped fiber; and by Exton U.S. Patent 4,063,282 for monitoring the growth of fatigue cracks in a specimen subjected to a pulsating load.

Yamaguchi et al U.S. Patent 4,449,818 uses different types of lighting to differentiate the types of irregularities on an object, using the brightness from oblique lighting to detect foreign substances on the surface of the object and perpendicular lighting to detect defects through shape recognition of a defect pattern. Recognition of irregular patterns is also shown in Hamada et al U.S. Patent 4,403,294 wherein an image signal is quantized as a binary code and then compared with a predetermined reference pattern to determine whether the visual image contains a defect pattern.

Watson U.S. Patent 3,389,789 shows a detector which is operated for marking or rejecting imperfect material when a video signal is of sufficient magnitude to exceed a threshold level of the detector and Gambrell et al U.S. Patent 3,379,829 uses flaw detection means for selectively inspecting certain preselected portions of glassware for flaws while ignoring other portions.

Inspection means have also been used for moving objects, such as mail, by Zeenkov U.S. Patent 3,868,478 who uses strobe lights to capture the image of an address on a letter by camera means for conveyance to television storage means and for display on a closed circuit television monitor.

Television monitoring cameras have also been used to monitor defects in moving sheets as shown in Decavel et al U.S. Patent 4,253,113. In Kopineck et al U.S. Patent 4,377,746, the optical image of such a moving sheet is stored for later viewing while Neiheisel et al U.S. Patent 4,223,346 uses a charge coupled array and a lens between the camera which will magnify the length of the field, i.e., the direction of travel of a moving band, without magnifying the width. Ohsumi et al U.S. Patent 4,219,844 detects the flaws in red hot slabs by adjusting the illumination to provide reflected light energy much larger than the radiation energy from

the metal part.

However, while the prior art has provided a number of defect detecting devices, there remains a need for means which will inspect a moving aluminum surface, such as provided by casting, rolling, extruding, and operations otherwise related to the production of aluminum products. The need is for detecting defects based on comparing an image pattern obtained using particular illumination techniques with a reference image pattern. When a difference in the image patterns is detected, the image containing the difference is automatically transmitted for viewing or electronic processing.

In accordance with the invention, there is provided a method of continuously and automatically monitoring broad surfaces of a rapidly moving metal material for the detection and analysis of surface variations which exceed established acceptable surface conditions for the purpose of determining the occurrence of surface defects that are considered rejectionable and for providing accurate defect classification of the same, comprising: homogeneously exposing the moving surface to visible and/or invisible specular and diffused electromagnetic radiation in a selected range of wavelengths to enhance surface features and thereby aid detection of surface defects, rendering the rapidly moving surface momentarily motionless detecting the presence of one or more rejectionable defects with a plurality of sensors located to view the entire width of the material, transmitting an electronic image of the area containing a defect from one or more of the sensors to a device for storing the image for subsequent display and analysis, the image containing grey scale levels that represent varying intensities of electromagnetic energy reflected by the defect, providing a range of grey scale levels that represent the range of intensities of electromagnetic energy reflected from a surface that is free of rejectionable defects, comparing the grey scale levels of the image with the defect with the range of grey scale levels that represent a surface free of rejectionable defects, and viewing and analyzing only those images of the surfaces on a freeze frame monitor that have grey scale levels outside the grey scale range of intensities that indicate a surface free from rejectionable defects.

The invention will be described with reference to the drawings in which;

Figure 1 is a schematic view of a portion of the detection system for carrying out the method of the invention and

Figure 2 is a block diagram of another portion of the detection system.

Referring now to Figure 1, a portion of a traveling metal sheet 10 is shown illuminated by a series of light sources 20, 30, 40, and 50. Sources 20 and

30 provide diffused lighting of the surface of metal sheet 10 while light sources 40 and 50 provide specular illumination of metal sheet 10.

An image of selected areas of illuminated metal sheet 10 is then captured by one or more video cameras 60 a through d which transmit corresponding electrical signals to respective video detectors 70 a through d. When an image containing one or more defects is detected by one or more of the detectors 70, a triggering signal is automatically sent to a video storage unit 80; unit 80 is comprised of multiple storage devices, one for each of the detectors 70. That particular image is stored by 80 for subsequent electronic analysis or visual viewing via a freeze frame monitor 90. Monitor 90 allows a workman to visually detect and quantify any rejectionable defect that actually exists over the complete width of sheet 10 passing beneath cameras 60.

Electronic evaluation of the image for defect characterization is effected by a processing device 95. Such a device is interfaced at 97 with the freeze frame monitor and with a more permanent storage means 100. Hence, the image stored in video store 80 may also be conducted to a more permanent storage means 100, which may comprise a videotape, a computer, a laser disc or other suitable storage means.

If desired, the image of the moving sheet may also be viewed in real time mode as well, such as from monitor 66 as shown in Figure 2. However, it will be appreciated that the human eye may not be able to continuously perceive defects detectable by detectors 70 at maximum production web speeds.

In accordance with a preferred embodiment of the invention, moving metal sheet 10 is illuminated by diffused and/or specular illumination to provide a more homogeneous coverage of the web surface. A combination of diffuse and specular illumination can be used to highlight variations in the surface being examined. Also, in a particularly preferred embodiment, the surface is illuminated by light in the long-wave invisible (red) portion of the spectrum to more fully match the sensitive spectrum of the image sensors used in video cameras and enhance the reflecting characteristics of the surface.

Being invisible, personnel are not hampered by high-intensity strobed illumination processes. The reflected or scattered energy from illumination sources 20, 30, 40, and 50 may be constant or may be strobed depending upon whether shuttered camera means are employed. Commercially available strobe lights or camera shutters can capture images of the moving surface at a rate of sixty or multiples of sixty per second. This typically will permit 100% down web inspection of a sheet surface travelling at 1800 feet per minute (or multiples

thereof) if the field of view (in the direction of travel) of the camera 60 represents one foot. In such case the image resolution represents 512 scan lines on the television screen, which is the NTSC television broadcast standard. In order to obtain a blur-free image of a moving surface, either the illumination source or the camera sensor must be strobed. This can be accomplished by either a pulsed illumination source or by a mechanically shuttered camera sensor. In both cases the illumination source utilized needs to be of high intensity.

As shown in Figure 2, the energy reflected from illuminated metal sheet 10 is captured by one or more video camera means 60 for conversion into an electrical signal which is transmitted to respective detectors 70. Video cameras suitable for the practice of the invention are readily available from commercial sources such as RCA, GE, Panasonic, Sony, and Phillips. Video detectors which may be used in the practice of the invention also comprise commercially available equipment such as a model 630 video detector, available from Colorado Video, Incorporated located in Boulder, Colorado.

From a standpoint of the width of the moving metal sheet, more than one camera can be used to cover the moving sheet area. As shown in Figure 1, four video camera means are mounted side by side to insure simultaneous inspection of the entire width of, for example, a 48-inch width metal sheet; this entire width is captured by 80 for display at 90. The number of cameras 60 required is dependent upon the detail of the surface variation to be detected. Optical magnification can provide the detail sought but reduces the field of view of the camera. As a consequence, more than one camera may be required if the field of view of the camera is less than the area of the surface of interest.

The reflected image, which is captured by video camera means 60, comprises varying intensities known in the art as gray scale levels. The particular grey scale levels, representing a metal surface free of defects, are empirically determined to calibrate the equipment using samples, respectively either free of defects, or containing certain types of known defects. Some defects will absorb or scatter more light than a defect-free surface while other defects will absorb or scatter less light than a defect-free surface. Hence, the equipment is standardized to provide both a minimum and a maximum gray scale level which represents the range of intensities that will be reflected from a surface free of defects.

When an electronic signal, such as from a surface defect, results in a gray scale level outside the standardized range, detector 70 senses this signal and activates the corresponding video unit

80 which will store for display of the image on monitor 90. Basic equipment to accomplish this is state-of-the-art. Thus the detection, storage, and display of images containing defects is automatic, requiring no visual and manual manipulation.

The stored image frame is displayed on monitor 90 to permit visual examination and study of the image purporting to contain a defect to determine whether or not a rejectionable defect actually exists. The image remains on monitor 90 until the occurrence of another defect or at the option of operating personnel.

As previously discussed, the image of the defect may also be transmitted to more permanent storage mediums such as videotape or disc (100) for visual or electronic evaluation and characterization by computer means.

Thus the invention provides a system for automatic monitoring of moving surfaces such as a moving metal sheet to detect defects on the surface and to transmit to a storage device an image of the particular portion of the surface containing a defect for visual and electronic characterization. In this way a large quantity of material may be rapidly surveyed with automatic equipment while an operator may more meticulously view images of only those portions of the moving object which the automatic equipment has singled out as possibly containing defects. Furthermore, by using specular and/or diffused illumination of selected wavelength, the sensitivity of the equipment to various types of defects is materially enhanced.

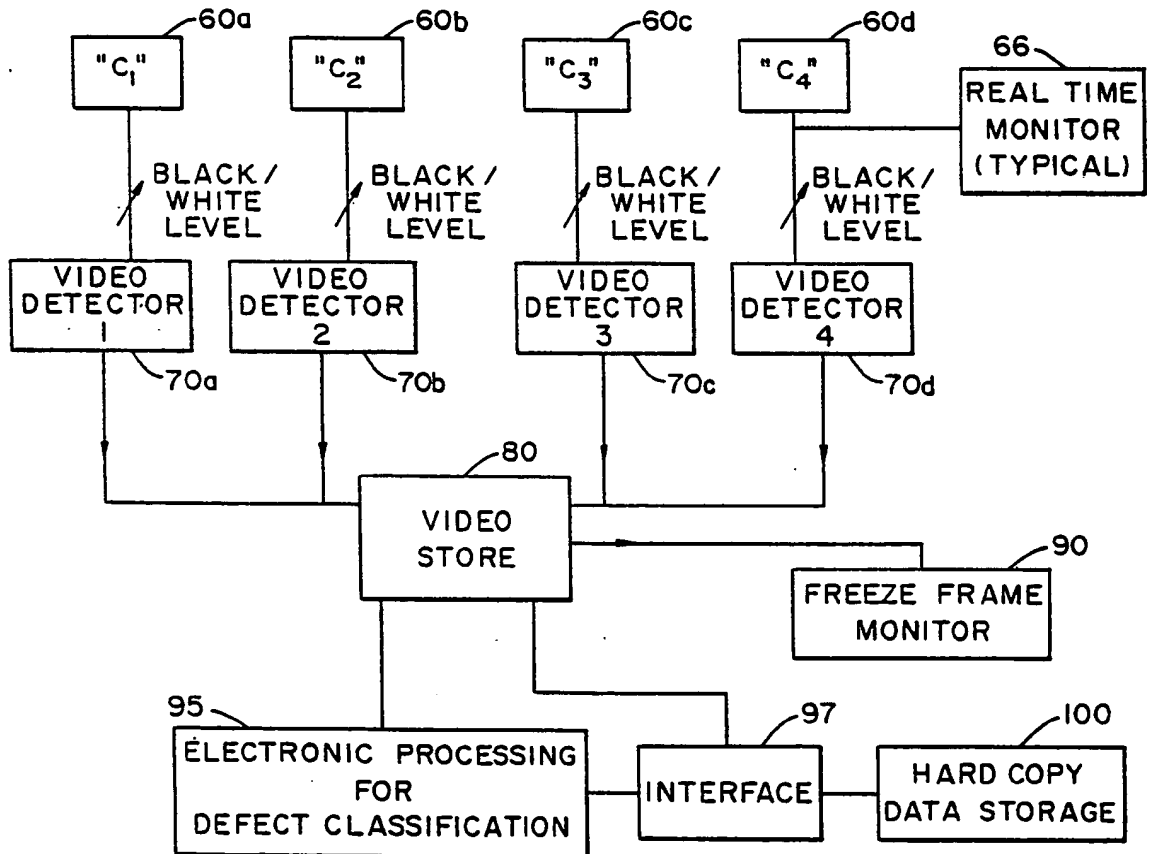
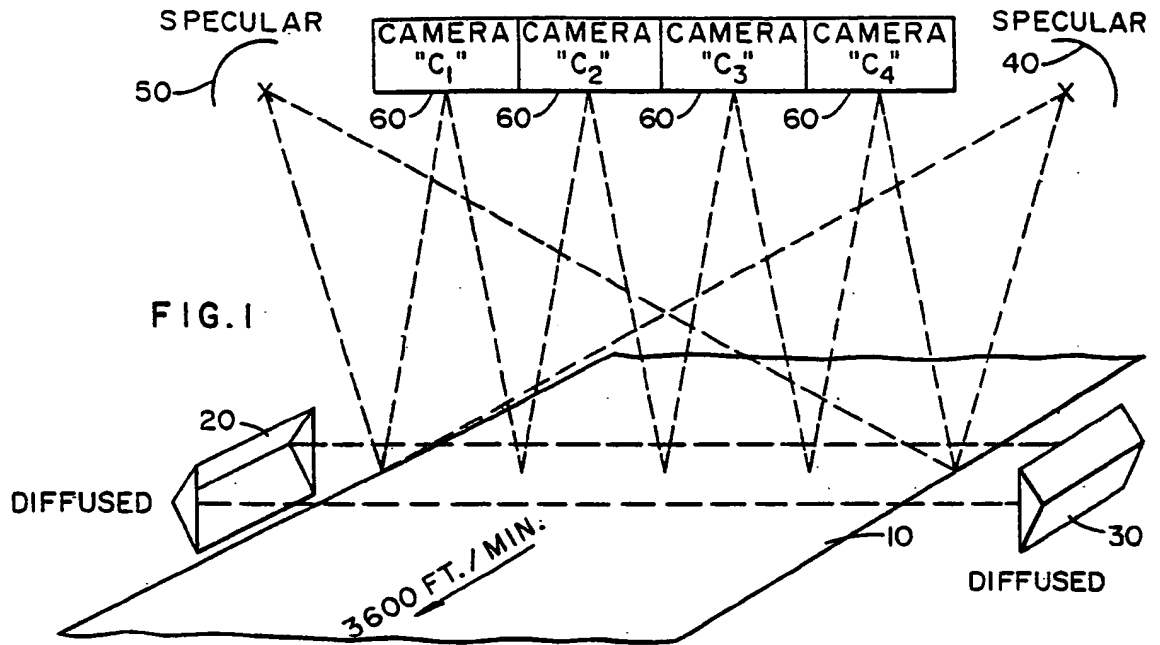
Claims

1. A method of continuously and automatically monitoring broad surfaces of a rapidly moving metal material for the detection and analysis of surface variations which exceed established acceptable surface conditions for the purpose of determining the occurrence of surface defects that are considered rejectionable and for providing accurate defect classification of the same, comprising: homogeneously exposing the moving surface to visible and/or invisible specular and diffused electromagnetic radiation in a selected range of wavelengths to enhance surface features and thereby aid detection of surface defects, rendering the rapidly moving surface momentarily motionless, detecting the presence of one or more rejectionable defects with a plurality of sensors located to view the entire width of the material, transmitting an electronic image of the area containing a defect from one or more of the sensors to a device for storing the image for subsequent display and analysis, the image containing grey scale levels that represent varying intensities of electromagnetic energy re-

flected by the defect, providing a range of grey scale levels that represent the range of intensities of electromagnetic energy reflected from a surface that is free of rejectionable defects, comparing the grey scale levels of the image with the defect with the range of grey scale levels that represent a surface free of rejectionable defects, and viewing and analyzing only those images of the surfaces on a freeze frame monitor that have grey scale levels outside the grey scale range of intensities that indicate a surface free from rejectionable defects.

2. A method according to claim 1, including the steps of: directing the specular light from a position above the moving surface while the diffused radiation is directed in a direction substantially parallel to the surface, with both types of radiation being positioned to homogeneously cover the entire width of the surface.

3. A method according to claim 1, in which defects are detected by capturing images of one or more rejectionable defects on the moving surface across the width thereof at a rate of sixty per second, or multiples thereof, for a distance of one foot of the surface in the direction of travel at a speed of 1800 feet per minute, or multiples thereof, using side-by-side video cameras employing the NTSC standard of 512 scan lines per frame.





DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
E	US-A-4 675 730 (P.R. ADOMAITIS et al.) * whole document *	1-3	G 01 N 21/89

A	PATENT ABSTRACTS OF JAPAN, vol. 8, no. 257 (P-316)[1694], 24th November 1984; & JP - A - 57 128 437 (TATEISHI DENKI K.K.) 24-07-1984	1,3	

A	US-A-4 110 047 (T. TAKAHASHI) * figures 4, 6, 7; column 2, line 40 - column 3, line 23; claims 1, 3, 4, 6 *	1,2	

A	FR-B-2 345 717 (HOESCH WERKE AG) * whole document *	1,2	
			TECHNICAL FIELDS SEARCHED (Int. Cl.4)
A	PATENT ABSTRACTS OF JAPAN, vol. 8, no. 55 (P-260)[1492], 13th March 1984; & JP - A - 58 204 353 (KAWASAKI SEITETSU K.K.) 29-11-1983	1,2	G 01 N 21/00 G 01 N 25/00

A,D	US-A-4 253 113 (B. DECAVEL et al.) * column 3, lines 34-68; claim 1 *	1	

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The present search report has been drawn up for all claims			
Place of search BERLIN		Date of completion of the search 28-09-1987	Examiner VINSOME R M
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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DOCUMENTS CONSIDERED TO BE RELEVANT															
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A	US-A-4 417 149 (A. TAKEUCHI et al.) * whole document *	1													
A	--- US-A-4 539 561 (G. WULFF) * whole document *	1													
A,D	--- US-A-4 219 844 (A. OHSUMI et al.) -----														
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (Int. Cl.4)												
Place of search BERLIN		Date of completion of the search 28-09-1987	Examiner VINSOME R M												
<table border="0"><tr><td>CATEGORY OF CITED DOCUMENTS</td><td></td></tr><tr><td>X : particularly relevant if taken alone</td><td>T : theory or principle underlying the invention</td></tr><tr><td>Y : particularly relevant if combined with another document of the same category</td><td>E : earlier patent document, but published on, or after the filing date</td></tr><tr><td>A : technological background</td><td>D : document cited in the application</td></tr><tr><td>O : non-written disclosure</td><td>L : document cited for other reasons</td></tr><tr><td>P : intermediate document</td><td>& : member of the same patent family, corresponding document</td></tr></table>				CATEGORY OF CITED DOCUMENTS		X : particularly relevant if taken alone	T : theory or principle underlying the invention	Y : particularly relevant if combined with another document of the same category	E : earlier patent document, but published on, or after the filing date	A : technological background	D : document cited in the application	O : non-written disclosure	L : document cited for other reasons	P : intermediate document	& : member of the same patent family, corresponding document
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